Energy Levels of Light Nuclei

\[ A = 7 \]

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Abstract: An evaluation of \( A = 5–10 \) was published in *Nuclear Physics A*413 (1984), p. 1. This version of \( A = 7 \) differs from the published version in that we have corrected some errors discovered after the article went to press. Figures and Introductory tables have been omitted from this manuscript. Also, Reference key numbers have been changed to the NNDC/TUNL format.

(References closed June 1, 1983)

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Table of Contents for $A = 7$

Below is a list of links for items found within the PDF document. Figures from this evaluation have been scanned in and are available on this website or via the link below.

A. Nuclides: $^7$H, $^7$He, $^7$Li, $^7$Be, $^7$B, $^7$C

B. Tables of Recommended Level Energies:

Table 7.1: Energy levels of $^7$He

Table 7.2: Energy levels of $^7$Li

Table 7.7: Energy levels of $^7$Be

C. References

D. Figures: $^7$Li, $^7$Be, Isobar diagram
\(^7\text{H}\)

(Not illustrated)

\(^7\text{H}\) has not been observed. Attempts have been made to detect it in the spontaneous fission of \(^{252}\text{Cf}\) (1982AL1H) and in the \(^7\text{Li}(\pi^-, \pi^+)\) reaction (1981EV01, 1981SE1J, 1981SE1B). See also (1979AJ01).

\(^7\text{He}\)

(Fig. 10)

GENERAL: (See also (1979AJ01).)


Other topics: (1979BE1H, 1981AV02, 1982AW02, 1982NG01).

1. \(^7\text{Li}(\pi^-, \gamma)^7\text{He}\)

\[ Q_m = 128.36 \]

See (1979AJ01).

Table 7.1: Energy levels of \(^7\text{He}\)

<table>
<thead>
<tr>
<th>(E_x) (MeV)</th>
<th>(J^\pi; T)</th>
<th>(\Gamma_{\text{c.m.}}) (keV)</th>
<th>Decay</th>
<th>Reactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>g.s.</td>
<td>((\frac{3}{2})^−; \frac{3}{2})</td>
<td>160 ± 30</td>
<td>n (^a)</td>
<td>1, 2, 3, 4</td>
</tr>
</tbody>
</table>

\(^a\) \(Q_0\) for \(^7\text{Li}(t, {}^3\text{He})^7\text{He}\) is \(-11.18\) MeV. This leads to \(26.11 ± 0.03\) MeV for the atomic mass excess of \(^3\text{He}\): \(Q_m\) for \(^7\text{He}_{\text{g.s.}}\) → \(^6\text{He} + n\) is then \(0.44 ± 0.03\) MeV: see (1979AJ01).

2. \(^7\text{Li}(n, p)^7\text{He}\)

\[ Q_m = -10.42 \]

At \(E_n = 14.8\) MeV a proton group is reported corresponding to \(^7\text{He}_{\text{g.s.}}\): \(\Gamma < 0.2\) MeV: see (1979AJ01). See also (1981BR1K).

3. \(^7\text{Li}(t, {}^3\text{He})^7\text{He}\)

\[ Q_m = -11.18 \]
The $^3$He particles to the ground state of $^7$He have been observed at $E_x = 22$ MeV. The width of the ground state is $160 \pm 30$ keV; for a radius of 2.2 fm and $l_n = 1$, this width is 0.22 of the Wigner limit. The angular distribution is peaked in the forward direction. No other states of $^7$He were observed for $E_x < 2.4$ MeV; see (1979AJ01).

4. $^9$Be($^6$Li, $^8$B)$^7$He

$Q_m = -23.60$

At $E(^6$Li) = 80.0 and 93.3 MeV the ground state of $^7$He is strongly populated, indicating negative parity, as expected. There is no indication of relatively sharp states of $^7$He with $E_x \leq 10$ MeV (1977WE03).
GENERAL: (See also (1979AJ01).)


$\mu = +3.256424 (2) \ \text{nm}$; see (1978LEZA)

$Q = (-34 \pm 6) \ e \cdot \text{mb}$; see (1980EG03). See also (1978LEZA, 1982MO13).

$B(\text{E2: } ^{3/2}_- \rightarrow ^{1/2}^-) = 8.3 \pm 0.6 \ e^2 \cdot \text{fm}^4$; see (1973HA47). See also (1979AJ01) and (1982BA52, 1982PE06).

1. $^3\text{H(}\alpha, \gamma)^7\text{Li}$

$Q_m = 2.4681$

Excitation functions and angular distributions have been studied for $E_\alpha = 0.5$ to 1.9 MeV. The cross section rises smoothly as expected for a direct-capture process: see (1966LA04). For calculations of the low-energy $S$-factor see (1981WI04). See also (1979YA1C; astrophysics).

2. $^3\text{H(}\alpha, \text{n})^6\text{Li}$

$Q_m = 4.7820 \quad E_b = 2.4681$

The cross section for this reaction has been measured for $E_\alpha = 11$ to 18 MeV: the data show the effect of $^7\text{Li}^*$(7.46) and indicate a broad resonance near $E_\alpha = 16.8$ MeV [$^7\text{Li}^*$(9.6)]. The level parameters derived from this reaction and from reaction 3 are displayed in Table 7.3. The yield of $^6\text{Li}$ ions at 0° (lab) has also been measured for $E_\alpha = 11.310$ to 11.930 MeV with 2–3% accuracy: the data were then reduced to obtain the cm differential cross sections at 0° and 180° for the inverse reaction in the energy region corresponding to formation of $^7\text{Li}^*$(7.46) (1977BR21). See also (1977KN1A).
Table 7.2: Energy levels of $^7$Li

<table>
<thead>
<tr>
<th>$E_x$ (MeV ± keV)</th>
<th>$J^\pi; T$</th>
<th>$\tau_m$ or $\Gamma_{c.m.}$ (keV)</th>
<th>Decay</th>
<th>Reactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>g.s.</td>
<td>$\frac{3}{2}^-$; $\frac{1}{2}$</td>
<td>$\tau_m = 105 \pm 5$ fsec $^a$</td>
<td>stable</td>
<td>1, 4, 5, 6, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 43, 44, 45, 46, 47, 48</td>
</tr>
<tr>
<td>0.477612 ± 0.003</td>
<td>$\frac{1}{2}^-$; $\frac{1}{2}$</td>
<td>$\Gamma = 93 \pm 8$ keV</td>
<td>$\gamma$</td>
<td>4, 5, 6, 11, 12, 14, 15, 16, 17, 18, 19, 20, 21, 24, 27, 28, 29, 30, 31, 32, 33, 34, 37, 38, 39, 41, 43, 45, 46, 47, 48</td>
</tr>
<tr>
<td>4.630 ± 9</td>
<td>$\frac{7}{2}^-$; $\frac{1}{2}$</td>
<td></td>
<td>t, $\alpha$</td>
<td>3, 5, 11, 12, 15, 16, 17, 18, 19, 20, 21, 31, 32, 34, 39, 42, 47</td>
</tr>
<tr>
<td>6.68 ± 50</td>
<td>$\frac{5}{2}^-$; $\frac{1}{2}$</td>
<td>$875^{+200}_{-100}$</td>
<td>t, $\alpha$</td>
<td>3, 12, 15, 16, 17, 18, 32, 39</td>
</tr>
<tr>
<td>7.4597 ± 1.2</td>
<td>$\frac{5}{2}^-$; $\frac{1}{2}$</td>
<td>89 ± 7</td>
<td>n, t, $\alpha$</td>
<td>2, 3, 7, 10, 12, 13, 15, 16, 18, 21, 29, 31, 32, 39</td>
</tr>
<tr>
<td>9.67 ± 100 $^b$</td>
<td>$\frac{7}{2}^-$; $\frac{1}{2}$</td>
<td>$\approx 400$</td>
<td>n, t, $\alpha$</td>
<td>2, 3, 7, 12, 16, 18, 32</td>
</tr>
<tr>
<td>9.85</td>
<td>$\frac{3}{2}^-$; $\frac{1}{2}$</td>
<td>$\approx 1200$</td>
<td>n, $\alpha$</td>
<td>7, 10, 29</td>
</tr>
<tr>
<td>11.24 ± 30</td>
<td>$\frac{3}{2}^-$; $\frac{3}{2}$</td>
<td>260 ± 35</td>
<td>n, p</td>
<td>7, 8, 15, 31</td>
</tr>
</tbody>
</table>

$^a$ See Table 7.2 in (1979AJ01) and Table 7.5.

$^b$ See also reactions 7 and 13 for additional states.
Table 7.3: $^7$Li levels from $^3$H + $^4$He $^a$

<table>
<thead>
<tr>
<th>$E_x$ (MeV + keV)</th>
<th>$J^\pi$</th>
<th>$l_\alpha$</th>
<th>$LS$ term</th>
<th>$R$ (fm)</th>
<th>$\theta^2_\alpha$ $^b$</th>
<th>$\theta^2_{n_0}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.65 ± 20</td>
<td>$^3$7−</td>
<td>3</td>
<td>$^2F_{7/2}$</td>
<td>4.0</td>
<td>0.57 ± 0.04</td>
<td></td>
</tr>
<tr>
<td>6.64 ± 100</td>
<td>$^3$7−</td>
<td>3</td>
<td>$^2F_{5/2}$</td>
<td>4.0</td>
<td>1.36 ± 0.13</td>
<td>0.000 ± 0.002</td>
</tr>
<tr>
<td>6.79 ± 90</td>
<td>$^3$7−</td>
<td>3</td>
<td>$^2F_{5/2}$</td>
<td>4.4</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td>7.47 ± 30</td>
<td>$^3$7−</td>
<td>3</td>
<td>$^4P_{5/2}$</td>
<td>4.0</td>
<td>0.011 ± 0.001</td>
<td>0.26 ± 0.02</td>
</tr>
<tr>
<td>9.67 ± 100</td>
<td>$^3$7−</td>
<td>3</td>
<td>$^4D_{7/2}$</td>
<td>4.0</td>
<td>0.53 ± 0.22</td>
<td>2.3 ± 0.7 $^c$</td>
</tr>
</tbody>
</table>

$^a$ For references see Table 7.3 in (1979AJ01).

$^b$ $\gamma^2/(\frac{1}{2}\hbar^2/\mu a^2)$.

$^c$ $\theta^2_{n_1}$ to $^6$Li*(2.19).

3. $^3$H($\alpha$, $\alpha$)$^3$H

The excitation curves for the elastic scattering show the effects of $^7$Li*(4.63, 6.68, 7.46, 9.67). The derived level parameters are displayed in Table 7.3. Angular distributions have been studied for $E_\alpha = 2.13$ to 2.98 MeV [see (1979AJ01)] and $E_t = 6.0$ to 17 MeV (1977BR21, 1980JA1F, 1981JA1G; very accurate $\sigma(\theta)$). Analyzing power measurements are reported for $E_t = 6.0$ to 17 MeV (1976HA17, 1980JA1F, 1981JA1G): a polarization extremum ($A_y = -1$) occurs near $E_t = 11.1$ MeV, $\theta_{c.m.} = 95^\circ$. There is some suggestion for a $J^\pi = \frac{1}{2}^-$ state in $^7$Li at $E_x = 9.6$ MeV (1981JA1G; N. Jarmie, private communication): see also reaction 7. The breakup of $^7$Li [at kinematic energy of 70 MeV] into $\alpha + t$ proceeds sequentially via $^7$Li*(4.63) when $^{12}$C is bombarded. When $^{208}$Pb is hit by $^7$Li, both this sequential process and breakup in the nuclear field of the $^{208}$Pb nucleus appear to occur (1981SH01). See also (1977KN1A, 1978BR1A) and (1977HA1E, 1978MI13, 1978TA1A, 1978TH1A, 1979LE1B, 1979WI1B, 1981AO02, 1981BE01, 1981FR1N, 1982FU01, 1982KA11, 1983AO03; theor.).

4. $^4$He($\alpha$, p)$^7$Li

$Q_m = -17.3459$

Angular distributions have been reported at $E_\alpha = 39.9$ to 49.5 MeV ($p_0$, $p_1$) and 60.2, 92.4 and 140.0 MeV ($p_{0+1}$) [see (1979AJ01)] and at $E_\alpha = 37.5$ to 43.0 MeV (1982SL01; $p_0$, $p_1$). See also (1978GL03, 1979AL1F), (1982RA1M; astrophys.) and $^8$Be.

5. $^4$He($^3$He, $\pi^+$)$^7$Li

$Q_m = -137.118$

At $E(^3$He) = 266.5 and 280.5 MeV, $^7$Li*(0 + 0.48, 4.63) are populated (1982BI06). See also (1982GE1C, 1982LE1L) and (1982KL1B; theor.).
6. $^6\text{Li}(n, \gamma)^7\text{Li}$

The thermal capture cross section is $38.5 \pm 3.0$ mb (1981MUZQ). Gamma rays are observed corresponding to transitions to $^7\text{Li}^*(0, 0.48)$ with branching ratios of $(61 \pm 3)$ and $(39 \pm 2)$%. $^7\text{Li}^*(4.63)$ is not involved in the decay [$\lesssim 2\%$]: see (1979AJ01). See also (1980BA34; theor.).

7. $^6\text{Li}(n, n)^6\text{Li}$

The scattering amplitude (bound) $a = 2.2 \pm 0.25 i$ fm, $\sigma_{\text{free}} = 0.45 \pm 0.08$ b. The thermal scattering cross section $\approx 0.75 \pm 0.02$ b (1981MUZQ). The total cross section has been measured from $E_n = 4$ eV to 49.6 MeV [see (1976GAYV)]. Recent measurements include those of (1982SM02: $E_n = 0.1$ to 0.8 MeV) and (1979LA1D, 1980KE1L; $E_n = 2.99$ to 49.64 MeV) and the integrated cross sections of (1979KN01; n0; 4.1 to 7.5 MeV) and (1979HO11; n0 and n1; 7.47 to 13.94 MeV). A pronounced resonance occurs at $E_n = 244.5 \pm 1.0$ keV with a peak cross section of $11.2 \pm 0.2$ b (1982SM02): see Table 7.4 [$E_\gamma = 7459.7 \pm 1.2$ keV]. No other clearly defined resonance is observed to $E_n = 49.6$ MeV although the total cross section exhibits a broad maximum at $E_n \approx 4.5$ MeV J.A. Harvey and N.W. Hill, private communication). The analyzing power has been measured for $E_n = 1.48$ to 4.38 MeV (1982DR06) and at 2 to 5 MeV (1975HO01, 1981CH12). An $R$-matrix analysis of the latter results as well as $\sigma_t$, $\sigma(\theta)$ and $(n, \alpha)$ results leads to a set of parameters for $^7\text{Li}$ states. These include a bound $\frac{1^+}{2}$ and an unbound $\frac{3^+}{2}$ state (at 9.38 ± 0.03 MeV) [neither reported in other reactions] as well as the $\frac{5}{2}^-$ state at 7.46 MeV [$\Gamma_\alpha = 33 \pm 1$ keV, reduced width $0.96 \pm 0.01$ MeV], a $\frac{7}{2}^-$ state at 9.16 ± 0.14 MeV [$\Gamma_\alpha = 2.09 \pm 0.18$ MeV, $\gamma^2 = 0.13 \pm 0.05$ MeV] and a $\frac{1}{2}^-$ state at 9.74 ± 0.05 MeV [no significant $\Gamma_\alpha$, $\gamma^2 = 1.87 \pm 0.18$ MeV] (1981CH12). Another recent $R$-matrix analysis (1983KN1G) suggests an unbound $\frac{1^+}{2}$ state at 8.81 MeV, a $\frac{3^+}{2}$ state at 9.97 MeV and a $\frac{1}{2}^-$ state at 10.31 MeV, in addition to the previously known states. The spectroscopic factors for the $l = 0$ decay to $^6\text{Li}_{g.s.}$ are $S = 0.2$ and 0.8 for $^7\text{Li}^*(8.81, 9.97)$. The states suggested by (1983KN1G) are very broad and cannot be seen directly in reaction or compound nucleus cross-section work (see also reaction 13). The two positive-parity states in $^7\text{Li}$ are consistent with the $^6\text{Li} + n$ scattering and reaction cross sections and provide an explanation for the anisotropy of the $^6\text{Li}(n, t)\alpha$ reaction at low energies (1983KN1G). See also (1982ST15; theor.).

The excitation function for 3.56 MeV $\gamma$-rays exhibits an anomaly, also seen in the (n, p) reaction (reaction 8). The data are well fitted assuming $E_{\text{res}} = 3.50$ and 4.60 MeV [$E_\gamma = 10.25 \pm 0.10$ and $11.19 \pm 0.05$ MeV], $T = \frac{1}{2}$ and $\frac{3}{2}$, $\Gamma_{\text{c.m.}} = 1.40 \pm 0.10$ and $0.27 \pm 0.05$ MeV, respectively; both $J^\pi = \frac{5}{2}^-$. The reduced widths for the $T = \frac{3}{2}$ state [$^7\text{Li}^*(11.19)$] are $\theta_\alpha^2 = 2 \times 10^{-4}$, $\theta_\nu^2 = 0.16$ [to $^6\text{Li}^*(3.56)$] and $\theta_p^2 = 0.09$: see also (1979AJ01) for a discussion of these and other (unpublished) data.

Table 7.4: Resonance parameters for 7.5-7.2 MeV levels in $^7$Li and $^7$Be $^a$

<table>
<thead>
<tr>
<th>Reaction</th>
<th>$^6$Li + n</th>
<th>$^6$Li + p</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_r$ (keV, lab)</td>
<td>262 $^b$</td>
<td>1840</td>
</tr>
<tr>
<td>$\Gamma(E_r)$ (keV, c.m.)</td>
<td>154</td>
<td>836</td>
</tr>
<tr>
<td>$E_\lambda$ (keV above g.s.)</td>
<td>7700</td>
<td>7580</td>
</tr>
<tr>
<td>$\Gamma_{n,p}(E_r)$ (keV, c.m.)</td>
<td>118</td>
<td>798</td>
</tr>
<tr>
<td>radius (n, p) in fm</td>
<td>3.94</td>
<td>4.08</td>
</tr>
<tr>
<td>$\gamma_{n,p}^2$ (MeV · fm)</td>
<td>4.85</td>
<td>5.02</td>
</tr>
<tr>
<td>$\theta_{n,p}^2$</td>
<td>0.26</td>
<td>0.28</td>
</tr>
<tr>
<td>$\Gamma_\alpha(E_r)$ (keV, c.m.)</td>
<td>36</td>
<td>38</td>
</tr>
<tr>
<td>radius ($\alpha$) in fm</td>
<td>4.39</td>
<td>4.39</td>
</tr>
<tr>
<td>$\gamma_{\alpha}^2$ (MeV · fm)</td>
<td>0.101</td>
<td>0.101</td>
</tr>
<tr>
<td>$\theta_{\alpha}^2$</td>
<td>0.012</td>
<td>0.012</td>
</tr>
</tbody>
</table>

$^a$ These states are believed to have a $^4P_{5/2}$ character, consistent with their large $\theta_n^2$ and $\theta_p^2$. For references see Table 7.4 in (1979AJ01).

$^b$ 244.5 ± 1.0 keV (1982SM02). See also (1981CH12).

8. (a) $^6$Li(n, 2n)$^5$Li $Q_m = -5.66$ $E_b = 7.2501$
   (b) $^6$Li(n, p)$^6$He $Q_m = -2.724$

For reaction (a) see (1976GO12). The excitation function, measured from threshold to $E_n = 8.9$ MeV, exhibits an anomaly at $E_n = 4.6$ MeV. The excitation function, at forward angles, of p$_0$ is approximately constant for $E_n = 4.4$ to 7.25 MeV: see (1979AJ01). See also $^6$He, (1980MI02) and (1982SH1K; applied).

9. $^6$Li(n, d)$^5$He $Q_m = -2.37$ $E_b = 7.2501$

The excitation function, at forward angles, of deuterons increases monotonically for $E_n = 5.4$ to 6.8 MeV: see (1979AJ01), $^5$He and (1982SH1K).

10. $^6$Li(n, $\alpha$)$^3$H $Q_m = 4.7820$ $E_b = 7.2501$
The isotopic thermal cross section is $940 \pm 4$ b; see (1981MIZQ). See also (1981EN01). Below 5 keV, the total cross section is given by $\sigma = (149.5/\sqrt{E} \text{ (eV)}) + 0.696$ b; see (1979AJ01). See also (1981IN1B). The $1/\nu$ dependence of the cross section (strong $l = 0$ waves) is not understood in terms of the known level structure of $^7$Li; see e.g. (1982SM02). In the 1 eV to 10 keV energy region, the ORNL results give an energy dependence for the asymmetry in the forward-to-backward $66^\circ$ cone (lab) of the form $A = 1 + 0.0055\sqrt{E_n}$, where $E_n$ is the energy in eV (J.A. Harvey and I.G. Schroder, private communication). See, however, reaction 7.

A resonance occurs at $E_n = 241 \pm 3$ keV with $\sigma_{\text{max}} = 3.15 \pm 0.08$ b (1978LA23; $E_n = 3$ to 800 keV), $3.36 \pm 0.6$ b (1978RE1B; $E_n = 80$ to 470 keV). The resonance is formed by p-waves, $J^\pi = \frac{3}{2}^-$, and has a large neutron width and a small $\alpha$-width: see Table 7.4. Above the resonance the cross section decreases monotonically to $E_n = 18.2$ MeV (1983BA17), except for a small bump near $E_n \approx 1.8$ MeV [see (1976GAYV, 1979AJ01)] and an inflection near $E_n = 3.5$ MeV, corresponding, presumably, to the anomaly reported in $(n, n'\gamma)$–see reaction 7–$[^7\text{Li}^*(10.25), J^\pi = \frac{3}{2}^-, T = \frac{1}{2}]$ (1979BA37; $E_n = 2.2$ to 9.7 MeV). See also (1980BA39).

Angular distributions have been measured at many energies in the range $E_n = 0.1$ to 7.3 MeV [see (1979AJ01)], 2 and 24 keV (1979ST03), 2.0 to 3.5 MeV (1982KNZZ), 2.16 to 9.66 MeV (1980BA39) and at 14.1 MeV (1982HI06). See also (1977HA1J).

(1979BO1E) report a right-left asymmetry for polarized thermal neutrons of $0.95 \pm 0.4 \times 10^{-4}$. Polarization measurements are reported by (1977KA06) for $E_n = 0.2$ to 2.4 MeV; the data suggest interference between s-waves and the p-wave resonance at 0.25 MeV. Interference between this $\frac{3}{2}^-$ state and a broad $\frac{5}{2}^-$ state 2 MeV higher also appears to contribute. At the higher energies $A_\varphi$ is close to +0.9 near 90$^\circ$ and varies slowly with $E_n$ (1977KA06). See also (1982KNZZ).


11. $^6\text{Li}(p, \pi^+)^7\text{Li}$ \hspace{2cm} $Q_m = -133.100$

At $E_p = 600$ MeV, the reaction preferentially excites $^7\text{Li}^*(4.63)$. Angular distributions have been obtained for the pions to $^7\text{Li}^*(0, 0.48, 4.63)$ at $E_p = 600$ MeV (1977BA37) and 800 MeV (1981NA1C). The $T = \frac{3}{2}$ state $^7\text{Li}^*(11.24)$ is not observed (1977BA37). See also (1980KE1D, 1981WI1F, 1982LE1L, 1982NA1K, 1982LO1B) and (1979ME2A, 1980WH1A).

12. (a) $^6\text{Li}(d, p)^7\text{Li}$ \hspace{2cm} $Q_m = 5.0255$

(b) $^6\text{Li}(d, np)^6\text{Li}$ \hspace{2cm} $Q_m = -2.22458$

(c) $^6\text{Li}(d, pt)^4\text{He}$ \hspace{2cm} $Q_m = 2.5574$

Angular distributions of proton groups have been studied for $E_d = 0.12$ to 15 MeV [see (1966LA04, 1974AJ01, 1979AJ01)] and at 698 MeV (1981BO03; $p_0 \rightarrow p_3$). $S = 0.90$ and
1.15 for $^7\text{Li}^*(0, 0.48)$ [DWBA analysis]; $J^\pi$ of $^7\text{Li}^*(0.48)$ is $1^{-}$. The two higher states have $E_x = 4.630 \pm 0.009$ and $7.464 \pm 0.010$ MeV, $\Gamma_{\text{c.m.}} = 93 \pm 8$ and $91 \pm 8$ keV. $^7\text{Li}^*(7.46)$ appears to be a $^2\text{P}$ state: see (1974AJ01). Reaction (b) at $E_d = 10$ MeV appears to proceed via $^7\text{Li}^*(7.46)$ and possibly $^7\text{Li}^*(9.6) [\Gamma = 0.5 \pm 0.1$ MeV]. Reaction (c) strongly involves $^7\text{Li}^*(4.63, 7.46)$ ($E_d = 7.5 \rightarrow 10.5$ MeV): see (1979AJ01). See also (1979HO04). For the breakup involving $^3\text{He}$ emission see (1979HO04). See also $^8\text{Be}$, (1981CE04) and (1979ME2A, 1980WH1A, 1982LO1B).

13. (a) $^7\text{Li}(\gamma, n)^6\text{Li}$
   $Q_m = -7.2501$
(b) $^7\text{Li}(\gamma, 2n)^5\text{Li}$
   $Q_m = -12.91$
(c) $^7\text{Li}(\gamma, p)^6\text{He}$
   $Q_m = -9.975$
(d) $^7\text{Li}(\gamma, pn)^5\text{He}$
   $Q_m = -11.84$
(e) $^7\text{Li}(\gamma, d)^5\text{He}$
   $Q_m = -9.62$
(f) $^7\text{Li}(\gamma, t)^4\text{He}$
   $Q_m = -2.4681$
(g) $^7\text{Li}(\gamma, pt)^3\text{H}$
   $Q_m = -22.2821$

The total photoneutron cross section rises sharply from 10 MeV to reach a broad plateau at about 15 mb from 14 to 20 MeV, decreases more slowly to about 0.5 mb at 25 MeV and then decreases further to about 0.3 mb at $E_\gamma = 30$ MeV (monoenergetic photons): there are indications of weak structure throughout the entire region. Differential cross sections for $n_0$ and $n_1$ have been reported for $E_\gamma = 7$ to 25 MeV. The integrated cross section to 23 MeV is $39 \pm 4$ MeV $\cdot$ mb for the $n_0$ transition and $17 \pm 4$ MeV $\cdot$ mb for the $n_1$ transition: together these account for 0.4 of the exchange augmented dipole sum of $^7\text{Li}$: see (1979AJ01). The integrated cross section for formation of $^6\text{Li}^*(3.56)$ is $4 \pm 1$ MeV $\cdot$ mb to 30 MeV and $11 \pm 3$ MeV $\cdot$ mb to 55 MeV (1978DE13).

The total absorption cross section for natural Li in the range 10 to 340 MeV shows a broad peak at $\approx 30$ MeV ($\sigma_{\text{max}} \approx 3$ mb), a minimum centered at $\approx 150$ MeV at $\approx 0.3$ mb and a fairly smooth increase in cross section to $\approx 3$ mb at $\approx 320$ MeV (1979AH1A, 1979ZI1A). See also the references in (1979AJ01).

The cross section for the $(\gamma, p)$ reaction (reaction (c)) shows a maximum at $\approx 15.6$ MeV with a width of $\approx 4$ MeV: see (1974AJ01). It then decreases fairly smoothly to 27 MeV (1979JU02). The integrated cross section for $11 \rightarrow 28$ MeV is $13.2 \pm 2.0$ MeV $\cdot$ mb (1979JU02). For the earlier work see (1979AJ01). Differential cross sections for the $(\gamma, n_0 + n_2)$ and $(\gamma, p_0)$ processes are reported by (1983SE07; $E_\gamma = 60$ to 120 MeV). Reaction (e) has been studied in the giant resonance reaction with $E_{\text{bs}} \lesssim 30$ MeV. Deuteron groups to $^3\text{He}_{g.s.}$ and possibly to the first excited state are reported. States of $^7\text{Li}$ with $E_x = 25 - 30$ MeV may be involved when $E_{\text{bs}} = 37$ to 50 MeV is used: see (1979AJ01). See also (1979JU02, 1982KIZW).

The cross section for reaction (f) at 90$^\circ$ displays a broad resonance at $E \approx 7.7$ MeV ($\Gamma = 7.2$ MeV) with an integrated cross section of 6.2 MeV $\cdot$ mb, a plateau for $12 \rightarrow 22$ MeV (at $\approx 0.6$ the cross section at 7.7 MeV) and a gradual decrease to 48 MeV. The $(\gamma, t)$ cross section integrated from threshold to 50 MeV is 8.1 MeV $\cdot$ mb (1979SK05; monoenergetic photons; angular distributions).

14. $^7$Li($\gamma$, $\gamma$)$^7$Li*

See Table 7.4 in (1966LA04) [summary of early measurements] for $\tau_m$ of $^7$Li*(0.48) = 107 ± 5 fsec. See also (1980IS1E, 1981IS06) and (1983ZH1D); theor.).

15. (a) $^7$Li(e, $e'$)$^7$Li*

(b) $^7$Li(e, ep)$^6$He $Q_m = -9.975$

(c) $^7$Li(e, en)$^6$Li $Q_m = -7.251$

(d) $^7$Li(e, et)$^4$He $Q_m = -2.467$

The electric form factor measurements for $E_e = 100$ to 600 MeV are well accounted for by a simple harmonic oscillator shell model with a quadrupole contribution described by an undeformed p-shell: $R_{rms} = 2.39 ± 0.03$ fm, $|Q| = 42 ± 2.5$ mb. From results obtained for $E_e = 24.14$ to 97.19 MeV, $R_{rms} = 2.35 ± 0.10$ fm (model independent), 2.29 ± 0.04 fm (shell model). A study of the ratio of the electric charge scattering from $^6$Li and from $^7$Li as a function of (momentum transfer)$^2$ yields $\langle r^2 \rangle_{^6Li}^{1/2}/\langle r^2 \rangle_{^7Li}^{1/2} = 1.001±0.008$. The rms radius of the ground-state magnetization density distribution, $\langle r^2 \rangle_{^6Li}^{1/2} = 2.98 ± 0.05$ fm. From the ratio of transverse inelastic and elastic cross sections at 180°, $B$(M1, ↑; 0.48) = 2.50 ± 0.12 $\mu_N^2$. The cross section for the longitudinal excitation of $^7$Li*(0.48) has been found from the scattering through angles of 90° to 150°, $B$(C2, ↑; 0.48) = 7 ± 4 fm$^4$; see (1979AJ01) for references. The form factor for $^7$Li*(0.48) has been measured at $\theta = 180°$ for $0.4 < q < 0.75$ fm$^{-1}$ (1982BU09): $\Gamma_0$(M1) = (7.5 ± 1.7) × 10$^{-3}$ eV, in good agreement with earlier values. Form factors for $^7$Li*(0, 0.48) are also reported for $0.8 < q < 2.9$ fm$^{-1}$ (1983LI07).

Inelastic scattering studies show peaks corresponding to $^7$Li*(4.63, 6.68, 7.46, 11.24) in addition to $^7$Li*(0.48); see (1974AJ01) and Table 7.5. Quasi-elastic processes have been studied by (1978KU06; 250 → 580 MeV/c). At $E_e = 700$ MeV the proton separation spectra (reaction (b)) are similar to those observed in (p, 2p) (1978NA05). See also (1980AS02) and $^6$He, $^6$Li for reactions (b) and (c). At $E_e = 450$ to 1096 MeV (1980TI05) have studied the contributions of longitudinal and transverse components of the cross section for inelastic scattering: the effect of meson-exchange currents is observed.

Table 7.5: Levels of $^7$Li from $^7$Li(e, e$'$) $^a$

<table>
<thead>
<tr>
<th>$E_x$ (MeV)</th>
<th>$J^\pi; T^\pi$</th>
<th>$\Gamma_{\gamma_0}$ (eV)</th>
<th>Type</th>
<th>$\Gamma_{\gamma_0}/\Gamma_W$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.48</td>
<td>$\frac{1}{2}^+; \frac{1}{2}$</td>
<td>$(2.8 \pm 1.6) \times 10^{-7}$</td>
<td>E2</td>
<td>17</td>
</tr>
<tr>
<td>4.63 ± 0.05 $^b$</td>
<td>$\frac{7}{2}^-; \frac{7}{2}$</td>
<td>$(6.30 \pm 0.31) \times 10^{-3}$</td>
<td>M1</td>
<td>2.8</td>
</tr>
<tr>
<td>6.6 ± 0.1 $^c$</td>
<td>$\frac{5}{2}^-; \frac{5}{2}$</td>
<td>0.6 ± 0.3</td>
<td>E2 $^d$</td>
<td></td>
</tr>
<tr>
<td>7.5 ± 0.08</td>
<td>$\frac{3}{2}^-; \frac{3}{2}$</td>
<td>0.9 ± 0.4 $^e$</td>
<td>E2</td>
<td></td>
</tr>
</tbody>
</table>

$^a$ For a summary of $B(E2\uparrow)$ measurements, see Table 7.6 in (1966LA04) and $^7$Li, the “GENERAL” section. For references see (1979AJ01). See also (1982PE06, 1983LI07).

$^b$ $B(E2\uparrow)[\frac{3}{2}^- \to \frac{7}{2}^-] = 17.5 e^2 \cdot \text{fm}^4$ (1982PE06).

$^c$ $\Gamma_{\text{c.m.}} = 875^{+200}_{-100}$ keV.

$^d$ Purely longitudinal.

$^e$ From $^7$Li(\gamma, n).

16. $^7$Li(\pi, \pi$'$)$^7$Li*

Angular distributions have been measured at $E_{\pi^+} = 49.7$ MeV (1978DY01; elastic), $E_{\pi^\pm} = 143$ MeV (1982GI01; to $^7$Li*(0, 0.48, 4.63, 6.68, 7.46, 9.67)) and 164.4 MeV (1979BO1F, 1979BO1G; to $^7$Li*(0, 0.48, 4.63, 6.68)). Total cross sections for $\pi$ on Li (from which partial cross sections were then derived) have been obtained for $\pi^+$ and $\pi^-$ at several energies in the range 85 $\to$ 315 MeV (1981AS07, 1979NA04). See also (1982OS01; theor.) and the “GENERAL” section here.

17. (a) $^7$Li(n, n$'$)$^7$Li*

(b) $^7$Li(n, nt)$^4$He $Q_m = -2.467$

Angular distributions have been measured at $E_n = 1.5$ to 14.6 MeV [see (1979AJ01)] and at $E_n = 4.1$ to 7.5 MeV (1979KN01; n$_{0+1}$), 6.97 to 13.94 MeV (1979HO11; n$_{0+1}$, n$_{0+2}$), 8.96 to 13.94 MeV (1979HO11; n$_2$), 9.1 MeV (1977BI12; n$_{0+1}$, n$_2$) and 10 to 18 MeV (1981DA1K; n$_0$). Reaction (b) at $E_n = 14.4$ MeV proceeds primarily via $^7$Li*(4.63) although some involvement of $^7$Li*(6.68) may also occur: see (1979AJ01). See also $^6$Li, (1979BA1R), (1980KA1R; applications) and (1982KO1U); theor.)

18. (a) $^7$Li(p, p$'$)$^7$Li*
Angular distributions of protons have been measured for $E_p = 49.8$ to 155 MeV: see (1974AJ01) and at $E_p = 24.4$ MeV (1982PE06; $p_0$, $p_1$, $p_2$). Inelastic proton groups have been observed corresponding to $^7\text{Li}^*(0.48, 4.63, 6.68, 7.46, 9.6 \pm 0.2)$: see (1952AJ38, 1974AJ01).

For reaction (b) see (1980CH05; 800 MeV), $^6$He and (1979AJ01). For reaction (c) see (1981ER10; 670 MeV) and $^5$He. Reaction (d) proceeds sequentially via $^7\text{Li}^*(4.63, 6.68)$. At $E_p = 100$ MeV (1977RO02) find $S_\alpha = 0.94 \pm 0.05$, using a DWIA analysis, a value close to that predicted by simple $LS$-coupling shell-model predictions. See also (1978LA11, 1980KI1D, 1982GO1H) and (1979AJ01). For reaction (e) see (1979AJ01) and (1982ER06; 670 MeV). See also $^8$Be, (1982YA1A) and (1978BA1C, 1978WO1A, 1979KI10, 1980KO1V, 1981IS11, 1982BA1W; theor.).

19. $^7\text{Li}(d, d')^7\text{Li}^*$

Angular distributions have been reported for $E_d = 1.0$ to 28 MeV: see (1974AJ01, 1979AJ01). See also $^9$Be.

20. $^7\text{Li}(^3\text{He}, ^3\text{He})^7\text{Li}$

Angular distributions are reported at $E(^3\text{He}) = 11$ MeV (elastic) [see (1974AJ01)], at 44.04 MeV (1979GO07; g.s.) and at $E(^3\text{He}) = 33.3$ MeV (1981BA37; $^7\text{Li}^*(0, 0.48, 4.63)$. See also $^{10}$B and (1979KA1G). At $E(^3\text{He}) = 37.5$ MeV, the three-body final states which are most strongly populated are the $^3\text{He} + \alpha + t$ and $^3\text{He} + d + ^5\text{He}$ branches. Detection of $^3\text{He}$–$t$ coincidences lead to a most probable momentum for the spectator $\alpha$-particle of 60 MeV/$c$; the $d$–$^3\text{He}$ breakup results suggest the unlikelihood of deuteron clusters in $^7\text{Li}$: see (1979AJ01).

21. (a) $^7\text{Li}(\alpha, \alpha')^7\text{Li}^*$
(b) $^7\text{Li}(\alpha, 2\alpha)^3\text{H}$ $Q_m = -2.4681$

Angular distributions (reaction (a)) have been reported for $E_\alpha = 3.6$ to 29.4 MeV [see (1974AJ01)] and at 5 and 6 MeV (1982WA23). Reaction (b) has been studied at $E_\alpha = 18$ to 64.3 MeV: see (1974AJ01) and (1980KI1D, 1980ZH1A). $^7\text{Li}^*(4.63)$ is strongly involved in the sequential decay. $^7\text{Li}^*(7.46)$ may also be involved. For pion production see (1981AB04). See also (1979ST25),

22. (a) \(^{7}\)Li\(^{6}\)Li, \(^{6}\)Li\(^{7}\)Li  
     (b) \(^{7}\)Li\(^{7}\)Li, \(^{7}\)Li\(^{7}\)Li

For reaction (a) see (1981GU1B; theor.). The elastic angular distribution (reaction (b)) has been studied for \(E(\text{Li}) = 4.0\) to 6.5 MeV: see (1974AJ01).

23. \(^{7}\)Li\(^{9}\)Be, \(^{9}\)Be\(^{7}\)Li

The elastic angular distribution has been measured at \(E(\text{Li}) = 34\) MeV (1977KE09).

24. (a) \(^{7}\)Li\(^{12}\)C, \(^{12}\)C\(^{7}\)Li  
     (b) \(^{7}\)Li\(^{13}\)C, \(^{13}\)C\(^{7}\)Li

The elastic scattering (reaction (a)) has been studied at \(E(\text{Li}) = 4.5\) to 36 MeV [see (1975AJ02, 1979AJ01)] and at 48, 63.0, 78.7 MeV (1979ZE01, 1980ZE03; also \(^{7}\)Li*\(^{11}\)C*(0.48) [and \(^{12}\)C*(0, 4.4)]) and 89 MeV (1979BR04; and \(^{12}\)C*(0, 4.4)). For elastic scattering studies involving \(^{13}\)C see (1979AJ01, 1981AJ01). For fusion measurements and yield curves see (1982DE30, 1982TA23). See also (1981SH01) and (1979SU1F, 1981GU1B, 1982CO16; theor.).

25. (a) \(^{7}\)Li\(^{15}\)N, \(^{15}\)N\(^{7}\)Li  
     (b) \(^{7}\)Li\(^{16}\)O, \(^{16}\)O\(^{7}\)Li  
     (c) \(^{7}\)Li\(^{20}\)Ne, \(^{20}\)Ne\(^{7}\)Li

The elastic scattering has been studied at \(E(\text{Li}) = 28.8\) MeV (1982WO09; reaction (a)), 68 and [reaction (c)] 89 MeV (1979BR03). See also (1979AJ01, 1979VA1B), (1980KH09, 1981GU1B; theor.) and \(^{20}\)Ne in (1983AJ01).

26. (a) \(^{7}\)Li\(^{24}\)Mg, \(^{24}\)Mg\(^{7}\)Li  
     (b) \(^{7}\)Li\(^{25}\)Mg, \(^{25}\)Mg\(^{7}\)Li  
     (c) \(^{7}\)Li\(^{26}\)Mg, \(^{26}\)Mg\(^{7}\)Li  
     (d) \(^{7}\)Li\(^{27}\)Al, \(^{27}\)Al\(^{7}\)Li
The elastic scattering has been studied at $E(^7\text{Li}) = 89$ MeV ($^{1980\text{CO11}},^{1980\text{ST06}},^{1981\text{CO05}},^{1982\text{CO16}},^{1982\text{CO18}}$), and at 27 MeV ($^{1982\text{WO09}}$; reaction (b)). See also ($^{1982\text{HN1A}},^{1982\text{TA23}}$, reaction (b)).

Angular distributions involving $^7\text{Li}^*(0, 0.48)$ and various states of $^{28}\text{Si}$ and $^{40}\text{Ca}$ have been studied at $E(^7\text{Li}) = 45$ MeV ($^{1982\text{EC01}}$). The elastic scattering (reactions (b) and (c)) has been studied at $E(^7\text{Li}) = 28$ and 34 MeV ($^{1977\text{CU02}}$), 88.7 MeV ($^{1980\text{ST06}}$) and 89 MeV ($^{1982\text{NA14}}$; also $^7\text{Li}^*(0.48)$). See also ($^{1982\text{HN1A}},^{1982\text{CO18}},^{1983\text{CO05}}$; theor.).

28. $^7\text{Be}(\gamma)^7\text{Li}$

The decay proceeds to the ground and 0.48 MeV states. The branching ratio to $^7\text{Li}^*(0.48)$ is $10.39 \pm 0.06\%$: see Table 7.6. A recent value of $15.4 \pm 0.8\%$ has been suggested by ($^{1982\text{ROZS}}$). However subsequently a number of groups have remeasured the branching ratio and find agreement with an earlier value. [In ($^{1979\text{AJ01}}$) the value of ($^{1974\text{GO26}}$) was improperly quoted; it is $(10.35 \pm 0.08)\%$.] The adopted half-life is $53.29 \pm 0.07$ d. Both transitions are superallowed: $\log ft = 3.32$ and 3.55 for the decays to $^7\text{Li}^*(0, 0.48)$. See ($^{1978\text{RA2A}},^{1979\text{AJ01}}$) for references.

The energy of the $\gamma$-ray is $477.605 \pm 0.003$ keV ($^{1978\text{HE21}}$), $477.6064 \pm 0.0026$ keV ($^{1983\text{KU03}}$) [$E_\gamma$ derived from the mean $E_\gamma$ is $477.612 \pm 0.002$ keV]. See also ($^{1978\text{SA1B}},^{1981\text{SA22}},^{1974\text{AJ01}},^{1979\text{HE19}},^{1980\text{VA1D}},^{1981\text{KH1E}},^{1982\text{MC1D}},^{1975\text{ZI1A}},^{1978\text{BA1E}},^{1979\text{DA1D}},^{1980\text{PE1N}},^{1981\text{BA1L}},^{1981\text{BA2G}},^{1982\text{BA80}},^{1982\text{CO1D}},^{1983\text{LI01}},^{1983\text{TR1F}}$; astrophysics) and ($^{1979\text{DE15}}$; theor.).

29. $^9\text{Be}(\pi^-, 2n)^7\text{Li}$

The capture of stopped pions has been studied in a kinematically complete experiment: $^7\text{Li}^*(0, 0.48)$ are weakly populated. Two large peaks are attributed to the excitation of $^7\text{Li}^*(7.46, 10.25)$ [see, however, Table 7.2]. The recoil momentum distributions corresponding to these peaks are rather similar and both indicate a strong $L = 0$ component ($^{1977\text{BA51}}$).

30. $^9\text{Be}(n, t)^7\text{Li}$

The capture of neutrons has been studied in a kinematically complete experiment: $^7\text{Li}^*(0, 0.48)$ are weakly populated. Two large peaks are attributed to the excitation of $^7\text{Li}^*(7.46, 10.25)$ [see, however, Table 7.2].
Table 7.6: The branching ratio of $^7$Be($\bar{\nu}$)$^7$Li to $^7$Li*(0.48) $^a$

<table>
<thead>
<tr>
<th>Branching ratio (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.32 ± 0.16</td>
<td>(1962TA11)</td>
</tr>
<tr>
<td>10.42 ± 0.18</td>
<td>(1973PO10)</td>
</tr>
<tr>
<td>10.35 ± 0.08</td>
<td>(1974GO26)</td>
</tr>
<tr>
<td>10.10 ± 0.45</td>
<td>(1983BA15)</td>
</tr>
<tr>
<td>10.61 ± 0.23</td>
<td>(1983DA14)</td>
</tr>
<tr>
<td>10.6 ± 0.5</td>
<td>(1983DO1M) $^c$</td>
</tr>
<tr>
<td>10.7 ± 0.3</td>
<td>(1983FIZV)</td>
</tr>
<tr>
<td>10.7 ± 0.2</td>
<td>(1983MA34)</td>
</tr>
<tr>
<td>9.8 ± 0.5</td>
<td>(1983NO03) $^c$</td>
</tr>
<tr>
<td>10.39 ± 0.06</td>
<td>weighted mean $^b$</td>
</tr>
</tbody>
</table>

$^b$ Not including the preliminary value of (1983FIZV).
$^c$ And private communication.

Angular distributions of the $t_0$ and $t_1$ groups are reported at $E_n = 13.99$ MeV: see (1979AJ01). See also (1978DR03) and $^{10}$Be.

31. $^9$Be(p, $^3$He)$^7$Li

$Q_m = -11.201$

At $E_p = 43.7$ MeV angular distributions have been obtained for the $^3$He particles corresponding to $^7$Li*(0, 0.48, 4.63, 7.46). The 7.46 MeV state is strongly excited while the mirror state in $^7$Be is not appreciably populated in the mirror reaction (see reaction 15 in $^7$Be). The angular distribution indicates that the transition to $^7$Li*(7.46) involves both $L = 0$ and 2, with a somewhat dominant $L = 0$ character. The $J^\pi = \frac{3}{2}^-$, $T = \frac{3}{2}$ state is located at $E_x = 11.28 \pm 0.04$ MeV, $\Gamma = 260 \pm 50$ keV: see (1979AJ01) for references. See also (1981DE1X).

32. (a) $^9$Be(d, $\alpha$)$^7$Li

(b) $^9$Be(d, t)$^4$He$^4$He

$Q_m = 7.152$

$Q_m = 4.6836$

Angular distributions have been measured for $E_d = 0.4$ to 27.5 MeV: see (1966LA04, 1974AJ01, 1979AJ01). A study at 11 MeV finds $\Gamma_{c.m.} = 93 \pm 25$ and $80 \pm 20$ keV, respectively, for $^7$Li*(4.63,
7.46). No evidence is found for the $T = \frac{3}{2}$ state $^7\text{Li}^*(11.25)$. In a kinematically complete study of reaction (b) at $E_d = 26.3$ MeV, $^7\text{Li}^*(4.6, 6.5 + 7.5, 9.4)$ are strongly excited. No sharp $\alpha$-decaying states of $^7\text{Li}$ are observed with $10 < E_\alpha < 25$ MeV. Parameters for $^7\text{Li}^*(9.7)$ are $E_\alpha = 9.36 \pm 0.05$ MeV, $\Gamma = 0.8 \pm 0.2$ MeV: see (1979AJ01). See also $^8\text{Be}$, $^{11}\text{B}$ in (1980AJ01, 1985AJ01) and (1980DE42, 1980DE43, 1980NE11, 1982LA09).

33. $^9\text{Be}(^6\text{Li}, ^8\text{Be})^7\text{Li}$

$$Q_m = 5.585$$

Angular distributions to $^7\text{Li}^*(0, 0.48)$ have been studied at $E(^6\text{Li}) = 5.5$ and 6.5 MeV: see (1979AJ01).

34. $^{10}\text{B}(n, \alpha)^7\text{Li}$

$$Q_m = 2.790$$

Angular distributions of $\alpha_0$, $\alpha_1$ and of $\alpha_2$ at the higher energies have been measured at $E_n = 0.2$ to 14.4 MeV [see (1979AJ01)] and at 2 and 24 keV (1979ST03; $\alpha_0$, $\alpha_1$). See also $^{11}\text{B}$ in (1980AJ01), (1978LI32) and (1980MU1D; applied).

35. $^{10}\text{B}(d, ^5\text{Li})^7\text{Li}$

$$Q_m = -1.40$$

See (1982DO1E; $E_d = 13.6$ MeV).

36. $^{10}\text{B}(\alpha, ^7\text{Be})^7\text{Li}$

$$Q_m = -16.200$$

See reaction 20 in $^7\text{Be}$.

37. $^{11}\text{Be}(\beta^-)^{11}\text{B}^* \rightarrow ^7\text{Li} + \alpha$

$$Q_m = 2.844$$

Delayed $\alpha$-particles have been observed in the $\beta^-$ decay of $^{11}\text{Be}$: they are due to the decay of $^{11}\text{B}^*(9.88) \left[ J^\pi = \frac{3}{2}^+ \right]$. This state decays by $\alpha$-emission $87.4 \pm 1.2\%$ to the ground state of $^7\text{Li}$ and $12.6 \pm 1.2\%$ to $^7\text{Li}^*(0.48)$ (1981AL03). See also $^{11}\text{Be}$, $^{11}\text{B}$ in (1985AJ01).

38. $^{11}\text{B}(d, ^6\text{Li})^7\text{Li}$

$$Q_m = -7.189$$
At $E_d = 13.6$ and 19.5 MeV angular distributions have been measured for the transitions to $^6\text{Li}_{\text{g.s.}}$ and $^7\text{Li}^*(0, 0.48)$: see $^6\text{Li}$.

39. $^{11}\text{B}(\alpha, ^8\text{Be})^7\text{Li}$ \hspace{1cm} $Q_m = -8.756$

Angular distributions have been measured at $E_\alpha = 27.2$ MeV (1983DO1F; see $^8\text{Be}$) and at $E_\alpha = 28.4$ and 29.0 MeV (to $^7\text{Li}^*(0, 0.48)$ and $^8\text{Be}^*(0, 2.9)$) and at 65 MeV (to $^7\text{Li}^*(0, 4.63)$). At $E_\alpha = 65$ and 72.5 MeV, $^7\text{Li}^*(0, 4.63)$ are very strongly populated while $^7\text{Li}^*(0.48, 6.68, 7.46)$ are weakly excited. See (1979AJ01) for references.

40. (a) $^{12}\text{C}(\gamma, p\alpha)^7\text{Li}$ \hspace{1cm} $Q_m = -24.6206$
   (b) $^{12}\text{C}(p, 2p\alpha)^7\text{Li}$ \hspace{1cm} $Q_m = -24.6206$

For reaction (a) see (1979KI04). For reaction (b) see (1981AU1D; astrophysics) and (1982ZH02; theor.).

41. $^{12}\text{C}(d, ^7\text{Be})^7\text{Li}$ \hspace{1cm} $Q_m = -17.539$

At $E_d = 39.8$ MeV, angular distributions have been measured for the transitions to $^7\text{Li}(0) + ^7\text{Be}(0)$, $^7\text{Li}^*(0.48) + ^7\text{Be}(0)$, $^7\text{Li}(0) + ^7\text{Be}^*(0.43)$, and $^7\text{Li}^*(0.48) + ^7\text{Be}(0.43)$. Assymetries exceeding 20% are observed in the ratio of the cross sections to $^7\text{Li}(0)$ and $^7\text{Be}(0)$: see (1979AJ01).

42. $^{12}\text{C}(\alpha, ^9\text{B})^7\text{Li}$ \hspace{1cm} $Q_m = -24.897$

At $E_\alpha = 65$ MeV this reaction proceeds via $^7\text{Li}^*(4.63)$ (1978SA26).

43. $^{12}\text{C}(^6\text{Li}, ^{11}\text{C})^7\text{Li}$ \hspace{1cm} $Q_m = -11.471$

Angular distributions have been obtained at $E( ^6\text{Li}) = 36$ MeV for the transitions to $^7\text{Li}^*(0, 0.48)$: see (1979AJ01).

44. $^{13}\text{C}(p, ^7\text{Be})^7\text{Li}$ \hspace{1cm} $Q_m = -20.261$
An angular distribution involving $^7\text{Li}_{g.s.} + ^7\text{Be}_{g.s.}$ has been measured at $E_p = 45.0$ MeV: see (1974AJ01).

45. $^{13}\text{C}(d, ^8\text{Be})^7\text{Li}$ 
\[Q_m = -3.5875\]

At $E_d = 14.6$ MeV angular distributions are reported for the transitions to $^7\text{Li}^*(0, 0.48)$ and $^8\text{Be}_{g.s.}$: see (1979AJ01). See also (1982DO1E) and $^8\text{Be}$.

46. $^{13}\text{C}(^6\text{Li}, ^{12}\text{C})^7\text{Li}$ 
\[Q_m = 2.304\]

At $E(^6\text{Li}) = 34$ MeV angular distributions have been measured for the transitions involving $^7\text{Li}_{g.s.} + ^{12}\text{C}_{g.s.}$, $^7\text{Li}^*_{0.48} + ^{12}\text{C}_{g.s.}$, $^7\text{Li}_{g.s.} + ^{12}\text{C}^*_{4.4}$, and $^7\text{Li}^*_{0.48} + ^{12}\text{C}^*_{4.4}$: see (1979AJ01).

47. $^{14}\text{N}(n, 2\alpha)^7\text{Li}$ 
\[Q_m = -8.8217\]

At $E_n = 14.1$ MeV, $^7\text{Li}^*(0, 0.48)$ are approximately equally populated. At $E_n = 18.2$ MeV, $^7\text{Li}^*(4.63)$ may be involved: see (1979AJ01).

48. (a) $^{17}\text{O}(d, ^{12}\text{C})^7\text{Li}$ 
\[Q_m = -2.580\]

(b) $^{18}\text{O}(d, ^{13}\text{C})^7\text{Li}$ 
\[Q_m = -5.678\]

(c) $^{19}\text{F}(d, ^{14}\text{N})^7\text{Li}$ 
\[Q_m = -6.122\]

At $E_d = 14.6$ to 15.0 MeV, angular distributions have been measured for the transitions to $^{12}\text{C}(0) + ^7\text{Li}^*(0, 0.48)$ [reaction (a)], $^{13}\text{C}(0) + ^7\text{Li}^*(0, 0.48)$ [reaction (b)] and $^{14}\text{N}(0) + ^7\text{Li}^*(0, 0.48)$ [reaction (c)]: see (1979AJ01). Angular distributions involving $^7\text{Li}^*(0, 0.48)$ are also reported at $E_d = 13.6$ MeV (reaction (b)) (1980GA1K).
7Be
(Figs. 9 and 10)

GENERAL: (See also (1979AJ01).)


Other topics: (1979BE1H, 1982NG01).

Ground state of 7Be: (1982FI13, 1982NG01).

1. 7Be(\(\epsilon\))7Li

\[ Q_m = 0.862 \]

The decay is complex: see 7Li.

2. 4He(3He, \(\gamma\))7Be

\[ Q_m = 1.5876 \]

The capture cross section has been measured for \(E_\alpha = 0.38 \) to 5.80 MeV [see (1974AJ01)], 0.250 to 2.954 MeV (1982KR05), 0.385 to 2.730 MeV (1982OS02), at \(E_{c.m.} = 0.897\) MeV (1983RO1C) and for \(E(3He) = 19 \) to 26 MeV (1983WA05; \(\gamma_{0+1} \) excitation function at 90°).

The branching ratios \(DC \rightarrow 429/DC \rightarrow 0\) and the cross section for the \(DC \rightarrow 429\) branch have been measured for \(E_{c.m.} = 107\) to 1266 keV: the branching ratio is approximately constant at 0.43 ± 0.02 over that energy range; the cross section is 0.117 ± 0.016 nb at 107 keV. It increases to 421 ± 39 nb at \(E_{c.m.} = 1266\) keV (1982KR05). These data lead to a value of \(S(0) = 0.56 \pm 0.03\) keV \(\cdot\) b (using microscopic DC model calculations, and a branching ratio, 10.42 ± 0.06%, for the 7Be decay to 7Li*(0.48)) [see reaction 28 in 7Li] (1983VO01).
Table 7.7: Energy levels of $^7$Be

<table>
<thead>
<tr>
<th>$E_x$ (MeV ± keV)</th>
<th>$J^π; T^e$</th>
<th>$\tau$ or $\Gamma_{c.m.}$</th>
<th>Decay</th>
<th>Reactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>g.s.</td>
<td>$\frac{1}{2}^-; \frac{1}{2}$</td>
<td>$\tau_{1/2} = 53.29 \pm 0.07$ d</td>
<td>$\epsilon$</td>
<td>1, 2, 5, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30</td>
</tr>
<tr>
<td>0.42908 ± 0.10</td>
<td>$\frac{1}{2}^-; \frac{1}{2}$</td>
<td>$\tau_{m} = 192 \pm 25$ fsec</td>
<td>$\gamma$</td>
<td>2, 5, 9, 10, 11, 12, 13, 14, 15, 17, 19, 22, 23, 24, 25, 27, 28, 29, 30</td>
</tr>
<tr>
<td>4.57 ± 50</td>
<td>$\frac{7}{2}^-; \frac{1}{2}$</td>
<td>$\Gamma = 175 \pm 7$ keV</td>
<td>$^3$He, $\alpha$</td>
<td>3, 10, 13, 14, 15</td>
</tr>
<tr>
<td>6.73 ± 100</td>
<td>$\frac{5}{2}^-; \frac{1}{2}$</td>
<td>1.2 MeV</td>
<td>$^3$He, $\alpha$</td>
<td>3, 8, 9, 13, 15</td>
</tr>
<tr>
<td>7.21 ± 60</td>
<td>$\frac{5}{2}^-; \frac{1}{2}$</td>
<td>$\leq 0.5$ MeV</td>
<td>p, $^3$He, $\alpha$</td>
<td>3, 6, 8, 9, 13</td>
</tr>
<tr>
<td>9.27 ± 100</td>
<td>$\frac{3}{2}^-; \frac{1}{2}$</td>
<td>$\approx 1.8$ MeV</td>
<td>p, $^3$He, $\alpha$</td>
<td>3</td>
</tr>
<tr>
<td>9.9</td>
<td>$\frac{5}{2}^-; \frac{1}{2}$</td>
<td>$\approx 1.8$ MeV</td>
<td>p, $^3$He, $\alpha$</td>
<td>3, 6</td>
</tr>
<tr>
<td>11.01 ± 30</td>
<td>$\frac{3}{2}^-; \frac{1}{2}$</td>
<td>320 ± 30</td>
<td>p, $^3$He, $\alpha$</td>
<td>3, 6, 13, 15</td>
</tr>
<tr>
<td>17</td>
<td>$\frac{3}{2}^-; \frac{1}{2}$</td>
<td>$\approx 6.5$ MeV</td>
<td>$^3$He</td>
<td>3, 13</td>
</tr>
</tbody>
</table>

(1982OS02) obtain $S(0) = 0.52 \pm 0.03$ keV · b and (1983RO1C) find $0.63 \pm 0.04$ keV · b. See also (1974AJ01) and (1981WI04; theor.). (1983RO1C) suggest, prior to (1983VO01), that $S(0) = 0.56 \pm 0.07$ keV · b should be adopted. $C^2 S = 1.0$ for $^7$Be*(0, 0.43) (1982KR05). See also (1980BA1P, 1980BA2M, 1980PE1N, 1981BA2F, 1981RO1W, 1982BA80; astrophysics) and (1981KI01, 1981LI01, 1982TA1G, 1983WA1M; theor.).

3. (a) $^4$He($^3$He, $^3$He)$^4$He
(b) $^4$He($^3$He, p)$^6$Li

$E_b = 1.5876$

| $Q_m$ | $-4.0182$ |

Elastic scattering studies have been reported for $E = 1.72$ to 140 MeV [see (1974AJ01, 1979AJ01)] and at $E_\alpha = 0.25$ to 2.95 MeV (1982KR05) and 140 MeV (1980RO03) and at $E(^3$He) = 18 to 70 MeV (1978BA75) and 198.4 MeV (1980RO03). Polarization measurements have been carried out at $E = 4.3$ to 98 MeV; see (1979AJ01).

For $l \leq 4$, only f-wave phase shifts show resonance structure for $E(^3$He) < 18 MeV, corresponding to $^7$Be*(4.57, 6.73, 9.27): see Table 7.7. No structure corresponding to $^7$Be*(7.21) ($J^π = \frac{5}{2}^-$) is seen in the elastic data. The s-wave phase shift is somewhat greater than hard-sphere. The decay of $^7$Be*(9.27) ($J^π = \frac{7}{2}^-$) to $^6$Li(0) requires f-shell configuration admixture. An estimate of the yield of ground-state protons relative to those corresponding to $^6$Li*(2.19) yields $\gamma^2(p_0)/\gamma^2(p_1) = (16^{+5}_{-10})%$. A phase-shift analysis (single-level $R$-matrix) has been carried out for

23
Table 7.8: $^7$Be levels from $^3$He + $^4$He $^a$

<table>
<thead>
<tr>
<th>$E_x$ (MeV ± keV)</th>
<th>$J^\pi$</th>
<th>$l_\alpha$</th>
<th>$LS$ term</th>
<th>$\theta_\alpha^2$ $^b$</th>
<th>$\theta_\alpha^2$ $^g$</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.57 ± 50</td>
<td>$^7/2^-$</td>
<td>3</td>
<td>$^2F_{7/2}$</td>
<td>0.70 ± 0.04</td>
<td></td>
</tr>
<tr>
<td>6.73 ± 100</td>
<td>$^5/2^-$</td>
<td>3</td>
<td>$^2F_{5/2}$</td>
<td>1.36 ± 0.13</td>
<td>0.000 ± 0.002</td>
</tr>
<tr>
<td>7.21 ± 60</td>
<td>$^5/2^-$</td>
<td>3</td>
<td>$^4P_{5/2}$</td>
<td>0.010 ± 0.001</td>
<td>0.26 ± 0.02</td>
</tr>
<tr>
<td>9.27 ± 100</td>
<td>$^7/2^-$</td>
<td>3</td>
<td>$^4D_{7/2}$</td>
<td>0.70 ± 0.26</td>
<td>0.29 ± 0.09 $^f$</td>
</tr>
<tr>
<td>10.0 $^c$</td>
<td>$^3/2^-$</td>
<td>1</td>
<td>$(^4P_{3/2})$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\approx$ 10.0 $^d$</td>
<td>$^1/2^-$</td>
<td>(4P1/2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.00 ± 50 $^e$</td>
<td>$^5/2^-$</td>
<td>1</td>
<td>$(^2P_{3/2}, ^2D_{3/2})$</td>
<td>0.13 ± 0.02 $^g$</td>
<td></td>
</tr>
</tbody>
</table>

$^a$ See also Table 7.10 in (1966LA04). For references see Table 7.7 in (1979AJ01).

$^b$ $\gamma^2/(3h^2/\mu a^2)$. $R = 4.0$ fm.

$^c$ $\Gamma = 1.8$ MeV.

$^d$ Broad.

$^e$ $\Gamma = 0.4 \pm 0.05$ MeV; $T = \frac{3}{2}$.

$^f$ $\theta_\pi^2 = 1.8 \pm 0.5$

$^g$ $\theta_\alpha^2$.

$E(^3\text{He}) = 18$ to $32$ MeV: the p-wave phase shifts indicate a $^1\!_2^-$ state at $E_x \approx 16.7$ MeV ($E_r = 26.4$ MeV), with $\Gamma = 6.5$ MeV (1978LU05). The work of (1978BA75) is consistent with the results of (1978LU05) and, in addition, suggests broad $l = 4$ and 5 states at $E(^3\text{He}) > 30$ MeV [$E_x > 19$ MeV].

The differential cross section for reaction (b) has been determined for $E(^3\text{He}) = 8$ to $28$ MeV [see (1979AJ01)] and at $E_x = 22.2$ to $26.5$ MeV (1980NE08; $p_0$). Resonances are observed corresponding to $^7\text{Be}^*(7.21, 9.27)$ in the $p_0$ yield, to $^7\text{Be}^*(9.27)$ in the $p_1$ yield and to states at $E_x \approx 10$ MeV ($T = \frac{1}{2}$) and $11.0$ MeV ($T = \frac{3}{2}$) in the yield of $3.56$ MeV $\gamma$-rays. The evidence for the latter derives mainly through interference arguments. There is also some evidence for an extremely broad $J^\pi = \frac{1}{2}^-$ structure at $E_x \geq 10$ MeV [see also $^6\text{Li}(p, p)$]: see Table 7.8 and (1974AJ01). See also (1980NE08). See also (1981BA1Q), (1978BR1A, 1979KA1G, 1982YA1A) and (1978DU1D, 1978TA1A, 1979KOZV, 1979LE11, 1979WI1B, 1981FI1B, 1981SH07, 1982AZ01, 1982FU01, 1982KA11, 1982LE23, 1983HO1F, 1983SA1G; theor.).

4. $^4\text{He}(\alpha, n)^7\text{Be}$

$Q_m = -18.9902$

See (1978GL03, 1979AL1F), (1979AJ01) and $^8\text{Be}$.

5. $^6\text{Li}(p, \gamma)^7\text{Be}$

$Q_m = 5.606$

24
Gamma transitions are observed to the ground ($\gamma_0$) and to the 0.43 MeV ($\gamma_1$) states. The yield shows no evidence of resonance for $E_p = 0.2$ to 1.0 MeV and the branching ratio remains approximately constant at $(62 \pm 5)\%$ to the ground state, $38\%$ to $^7\text{Be}^*(0.43)$, $< 4\%$ to $^7\text{Be}^*(4.57)$: see (1974AJ01). The total cross section for $E_p = 0.2$ to 1.2 MeV has been obtained by (1979SW02): at $E_p = 0.8$ MeV it is $3.1 \pm 0.4 \mu$b, in good agreement with previous values. The branching ratio to $^7\text{Be}^*(0.43)$ is $(41 \pm 3)\%$ (1979SW02). The weighted mean of this and previous measurements is $(39 \pm 2)\%$ (1979SW02). See also (1980BA34).

6. (a) $^6\text{Li}(p, p)^6\text{Li}$  
(b) $^6\text{Li}(p, 2p)^5\text{He}$  
(c) $^6\text{Li}(p, p\alpha)^2\text{H}$  

$Q_m = -4.59$  
$Q_m = -1.4753$

Measurements of elastic angular distributions have been reported for $E_p = 0.5$ to 600 MeV: see (1966LA04, 1974AJ01) and $^6\text{Li}$. Two resonances are reported at $E_p = 1.84$ and 5 MeV in the elastic yield [$^7\text{Be}^*(7.21, 9.9)$]. The parameters of the lower resonance are shown in Table 7.4. The 5 MeV resonance has $\Gamma \approx 1.8$ MeV and appears to also be formed by p-waves: $\gamma_2^p$ is then $3 \pm 2$ MeV · fm. A weak rise near $E_p = 8$ to 9 MeV may indicate a further level, $^7\text{Be}^* \approx 13$ MeV. A broad resonance at $E_p = 14$ MeV has also been suggested. Polarization measurements have been carried out for $E_p = 1.2$ to 155 MeV [see (1974AJ01, 1979AJ01)] and at $E_p = 25$ and 35 MeV (1982ROZT; $p_0, p_1$) and 800 MeV (1979GL1C; $p_2$). A phase shift analysis for $E_p = 0.5$ to 5.6 MeV shows that only $^2\text{S}$, $^4\text{S}$ and $^4\text{P}$ are involved. The $^4\text{P}_{5/2}$ phase resonates at $E_p = 1.8$ MeV, and the broad resonance at 5 MeV can be reproduced equally well by either $^4\text{P}_{3/2}$ or $^4\text{P}_{1/2}$: tensor polarization measurements are necessary to distinguish between the two: see (1974AJ01).

The reaction cross section for formation of $^6\text{Li}^*(2.19)$ has been measured for $E_p = 3.6$ to 9.40 MeV: a broad resonance indicates the presence of a state with $E_x \approx 10$ MeV, $\Gamma = 1.8$ MeV, $J^\pi = (\frac{3}{2}, \frac{5}{2})^-$, $T = \frac{1}{2}$. The cross section and angular distributions of $p_2$ ($^6\text{Li}^*(3.56)$) for $E_p = 4.26$ to 9.40 MeV is analyzed in terms of two $J^\pi = \frac{3}{2}^-$ states at $E_x \approx 10$ and 11 MeV; see reaction 3. The total cross section for formation of $^6\text{Li}^*(3.56)$ decreases slowly with energy for $E_p = 24.3$ to 46.4 MeV. The reaction cross section has been measured for $E_p = 25.0$ to 48 MeV: see (1979AJ01).

For reaction (b) see $^5\text{He}$, (1978NA18; $E_p = 635$ MeV) and (1979AJ01). For reaction (c) see $^6\text{Li}$ and (1979AJ01). Studies of inclusive cross sections are reported at 640 MeV (1981ER07) and 400 GeV (1979BA28, 1979FR12, 1980NI09). For pion and kaon production see (1980NI09; 400 GeV). See also (1982AB1D) and (1981FR1R, 1981FR1T, 1981KR15, 1982ST15; theor.).

7. $^6\text{Li}(p, n)^6\text{Be}$  

$Q_m = -5.070$  
$E_b = 5.606$

The yield of neutrons increases approximately monotonically from threshold to $E_p = 14.3$ MeV. Polarization measurements are reported at $E_p = 30$ and 50 MeV: see (1974AJ01). See also $^6\text{Be}$.
8. $^6\text{Li}(p, \alpha)^3\text{He}$

$$Q_m = 4.0182$$

$$E_b = 5.606$$

$$Q_0 = 4018.2 \pm 1.1 \text{ keV}; \text{ see (1981RO02)}$$

Over the range $E_p = 25$ to 50 keV, the cross section rises from 0.8 to 72 $\mu$b: in the formula

$$\sigma \approx E^{-1} e^{-B/\sqrt{E}}, \quad B = 90 \pm 6 \text{ keV}^{1/2}. $$

Cross-section measurements for $E_p = 62$ to 188 keV show deviation from an s-wave Gamow plot above $\approx 130 \text{ keV}$ (1966GE11). Using cross-section measurements at $E_p = 136 \rightarrow 297 \text{ keV}$, as well as the (1966GE11) results, (1979EL10) calculate $S(0) = 3.145 \text{ MeV} \cdot \text{b} \mid E_c, m, \mu = 1 \text{ keV}$. Thermonuclear reaction rates are also derived (1979EL10). See also (1979SH14; 125 \rightarrow 700 \text{ keV}; S(0) = 3 \text{ MeV} \cdot \text{b}) and (1979AJ01).

At higher energies the cross section exhibits a broad, low maximum near $E_p = 1.85 \text{ MeV}$ ($\Gamma < 0.5 \text{ MeV}$). No other structure is reported up to $E_p = 1.9 \text{ MeV}$ resonance appears in $A_1$ and $A_2$: see (1974AJ01).

Angular distributions have been reported for $E_p = 0.15$ to 45 MeV [see (1974AJ01, 1979AJ01)] and at $E_p = 125$ to 700 keV (1979SH14), 136 to 297 keV (1979EL10) and 47.8, 53.5, 58.5 and 62.5 MeV (1982BA1V). See also (1979DE1E, 1979HA1C, 1980HA1Y, 1981JA1F; applied), (1981HO1E) and (1978PL1A; theor.).

9. $^6\text{Li}(d, n)^7\text{Be}$

$$Q_m = 3.381$$

Angular distributions of the $n_0$ and $n_1$ groups have been measured at $E_d = 0.20$ to 15.25 MeV: see (1974AJ01, 1979AJ01). The n-\gamma correlations are isotropic, indicating $J^\pi = \frac{1}{2}^-$ for $^7\text{Be}^*(0.43)$. Broad maxima are observed in the ratio of low-energy to high-energy neutrons at $E_d = 4.2$ and 5.1 MeV [$^7\text{Be}^*(6.5, 7.2), \Gamma_{c.m.} = 1.2$ and 0.5 MeV, respectively]: see (1966LA04). See also (1979HO04, 1980GU26) in $^8\text{Be}$.

10. $^6\text{Li}(^3\text{He}, d)^7\text{Be}$

$$Q_m = 0.112$$

Angular distributions of the $d_0$ and $d_1$ groups to $^7\text{Be}^*(0, 0.43)$ have been measured at $E(^3\text{He}) = 8, 10, 14$ and 18 MeV: all the distributions show an $l = 1$ maximum at small angles: see (1974AJ01). At $E(^3\text{He}) = 33.3$ MeV angular distributions and $A_y$ measurements to $^7\text{Be}^*(0, 0.43)$ have been analyzed using coupled channels and DWBA. $^7\text{Be}^*(4.57)$ is also populated (1981BA38).

11. $^6\text{Li}(\alpha, t)^7\text{Be}$

$$Q_m = -14.208$$

See (1979AJ01).
12. (a) $^7\text{Li}(\gamma, \pi^-)^7\text{Be}$ \quad $Q_m = -140.429$
(b) $^7\text{Li}(\pi^+, \pi^-)^7\text{Be}$ \quad $Q_m = 3.742$

For reaction (a) see (1979BO23). Forward-angle differential cross sections to $^7\text{Be}_{g.s.}$ have been measured at $E_{\pi^+} = 48$ MeV (1982LEZY), and $70 \rightarrow 180$ MeV (1980BA27, 1982DO02). See also (1982AL35).

13. $^7\text{Li}(p, n)^7\text{Be}$ \quad $Q_m = -1.644$

The excitation energy of $^7\text{Be}^*(0.43)$ is $429.20 \pm 0.10$ keV, $\tau_m = 192 \pm 25$ fsec: see (1979AJ01). Angular distributions of $n_0$ and $n_1$ are reported at $E_p = 1.9$ to 50 MeV [see (1974AJ01, 1979AJ01)] and at 119.8 MeV (1979GO16, 1980GO07; $n_{0+1}$). The population of $^7\text{Be}^*(4.55, 6.51, 7.19, 10.79)$ has also been observed: see (1974AJ01, 1979AJ01). The ratios $\sigma_1/\sigma_0$ ($^7\text{Be}^*(0.43)/^7\text{Be}_{g.s}$) have been measured at 24.8, 35 and 45 MeV: an analysis of these yields the ratio of spin-flip to spin-nonflip strength $|V_{\sigma\tau}/V_{\tau\tau}|^2$ (1980AU02). (1983TAZY) report cross-section measurements at $E_p = 60$ to 200 MeV. See also (1981SH1F, 1982KI1F, 1982TAZQ), (1979CH1B, 1980SE1D, 1982SA1M; applied), (1982GO1C, 1982PE06, 1982TA03), (1982GU1D, 1983GU1G; theor.) and $^8\text{Be}$.

14. $^7\text{Li}^3\text{He}, t)^7\text{Be}$ \quad $Q_m = -0.881$

Angular distributions of $t_0$ and $t_1$ have been measured at $E(\text{}^3\text{He}) = 3.0$ to 4.0 MeV [see (1974AJ01)] and at $E(\text{}^3\text{He}) = 33.3$ MeV (1981BA37). The width of $^7\text{Be}^*(4.57)$, $\Gamma_{c.m.} = 175 \pm 7$ keV: see (1974AJ01). See also $^{10}\text{B}$.

15. $^9\text{Be}(p, t)^7\text{Be}$ \quad $Q_m = -12.082$

Angular distributions of tritons have been measured at $E_p = 43.7$ MeV ($^7\text{Be}^*(0, 0.43, 4.57, 6.51, 11.01)$) and 46 MeV ($^7\text{Be}^*(0 + 0.43, 4.57, 6.51, 10.69)$), and at $E_p = 50$ and 72 MeV (1982ZA1B; $t_0$, $t_1$). The 11 MeV state has $E_x = 11.01 \pm 0.04$ MeV, $\Gamma = 298 \pm 25$ keV, $J^\pi = 3^-$, $T = \frac{3}{2}$ [the $J^\pi$; $T$ assignments are based on the similarity of the angular distribution to that in the $(p, ^3\text{He})$ reaction to $^7\text{Li}^*(11.13)$]: see (1979AJ01).

16. $^9\text{Be}^3\text{He}, ^5\text{He})^7\text{Be}$ \quad $Q_m = -0.88$
See reaction 23 in $^5$He.

17. $^{10}\text{B}(p, \alpha)^7\text{Be}$  
$$Q_m = 1.146$$

Angular distributions have been measured for $E_p = 2.8$ to 7.0 MeV: see (1974AJ01). $E_x = 428.89 \pm 0.13$ keV (1979RI12). See also $^{11}\text{C}$ in (1980AJ01, 1985AJ01).

18. $^{10}\text{B}(d, ^5\text{He})^7\text{Be}$  
$$Q_m = -1.97$$

See (1982DO1E).

19. $^{10}\text{B}(^3\text{He}, ^6\text{Li})^7\text{Be}$  
$$Q_m = -2.873$$

See $^6\text{Li}$.

20. $^{10}\text{B}(\alpha, ^7\text{Li})^7\text{Be}$  
$$Q_m = -16.200$$

At $E_\alpha = 45.6$ MeV the angular distributions of the $^7\text{Li}$ and of the $^7\text{Be}$ ions, corresponding to the ground-state transitions, have been measured. At a given angle the intensities of the two ions are the same, implying that the wave functions of the ground states of $^7\text{Li}$ and $^7\text{Be}$ are very similar: see (1974AJ01).

21. $^{12}\text{C}(\gamma, n\alpha)^7\text{Be}$  
$$Q_m = -26.265$$

See (1979KI04).

22. $^{12}\text{C}(p, ^6\text{Li})^7\text{Be}$  
$$Q_m = -22.565$$

See $^6\text{Li}$.

23. $^{12}\text{C}(d, ^7\text{Li})^7\text{Be}$  
$$Q_m = -17.539$$
See \(^7\)Li.

24. \(^{12}\)C(\(^3\)He, \(^8\)Be)\(^7\)Be \(Q_m = -5.779\)

Angular distributions are reported at \(E(\(^3\)He) = 25.5\) to 30 MeV involving \(^7\)Be\(^*(0, 0.43)\) [see (1979AJ01)] and at 41 MeV (1981LE01) and \(^{16}\)O in (1981AJ01).

25. \(^{12}\)C(\(\alpha\), \(^9\)Be)\(^7\)Be \(Q_m = -24.691\)

At \(E_\alpha = 42\) MeV, angular distributions have been measured involving \(^7\)Be\(^*(0, 0.43)\) and \(^9\)Be\(_{g.s.}\); see (1974AJ01).

26. \(^{13}\)C(p, \(^7\)Li)\(^7\)Be \(Q_m = -20.261\)

See \(^7\)Li.

27. \(^{16}\)O(\(^3\)He, \(^{12}\)C)\(^7\)Be \(Q_m = -5.5744\)

Angular distributions are reported at \(E(\(^3\)He) = 25.5, 30\) and 70 MeV to \(^7\)Be\(^*(0, 0.43)\) and various states of \(^{12}\)C [see \(^{12}\)C in (1980AJ01)] and at 41 MeV (1981LE01).

28. \(^{16}\)O(\(\alpha\), \(^{13}\)C)\(^7\)Be \(Q_m = -21.2058\)

See \(^{13}\)C in (1981AJ01).

29. \(^{19}\)F(d, \(^{14}\)C)\(^7\)Be \(Q_m = -7.140\)

The angular distributions to \(^7\)Be\(^*(0, 0.43)\) + \(^{14}\)C\(_{g.s.}\) has been measured at \(E_d = 14.9\) MeV; see (1974AJ01).

30. (a) \(^{19}\)F(\(^3\)He, \(^{15}\)N)\(^7\)Be \(Q_m = -2.426\)

(b) \(^{20}\)Ne(\(^3\)He, \(^{16}\)O)\(^7\)Be \(Q_m = -3.146\)
See $^{15}$N in (1981AJ01) and $^{16}$O in (1982AJ01).

$^7$B
(Fig. 10)

GENERAL: (See also (1979AJ01).)

See (1979BE1H, 1982NG01).

Mass of $^7$B: This nucleus has been studied in the $^7$Li($\pi^+, \pi^-)^7$B and $^{10}$B($^3$He, $^6$He)$^7$B reactions. In the ($\pi^+, \pi^-$) work (1981SE1B; preliminary) find the mass excess to be $27.80 \pm 0.10$ MeV and $\Gamma$ for the ground state is $1.2 \pm 0.2$ MeV. In the earlier ($^3$He, $^6$He) work [see (1974AJ01)] $M - A$ was reported to be $27.94 \pm 0.10$ MeV, $\Gamma = 1.4 \pm 0.2$ MeV. We adopt $27.87 \pm 0.10$ MeV, $\Gamma = 1.3 \pm 0.2$ MeV. The isobaric quartet mass law would predict $M - A = 27.76 \pm 0.17$ MeV. $^7$B is unbound with respect to $^6$Be + p ($Q = 2.21$), $^5$Li + 2p ($Q = 1.61$), $^4$He + 3p ($Q = 3.58$). The expected single-particle width is $\Gamma = 0.64$ MeV; it is suggested that the two-proton and three-proton decays make an appreciable contribution to the width: see (1974AJ01).

$^7$C
(Not illustrated)

Not observed: see (1982NG01; theor.).
References

(Closed 1 June 1983)

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